CMPG-767 Digital Image Processing

SPATIAL DOMAIN FILTERING SHARPENING FILTERS

Sharpening

- The principal objective of sharpening is to highlight transitions in intensity
- While image smoothing can be achieved by averaging (integration) in a local neighborhood, which leads to suppression of high frequencies, image sharpening can be accomplished by differentiation in a local neighborhood, which leads to the high and possibly medium frequencies enhancement

Sharpening

- There are two types of sharpening :
- Using high-pass filters – these filters suppress or eliminate low and medium frequencies, passing and possibly enhancing high frequencies. This is resulted in edge detection and edge enhancement
- Using frequency correcting filters – these filters enhance high and possibly medium frequencies, which leads to image sharpening and distinguishing of the details whose area is about a half by a half of the filtering window size

Frequency Correcting Filters

- Frequency correcting filters enhance high and possibly medium frequencies, which leads to visual image sharpening and visual distinguishing of the details whose area is about a half by a half of the filtering window size
- It is important to understand that these filters improve visual perception, but they cannot restore missing frequencies. Thus, they cannot be used for image deblurring
- These filters are also called image preparation filters

Unsharp Masking

- Unsharp masking is a classical frequency corrector
- High frequencies enhancement is utilized through a filter, which adds the “unsharp mask” to an image
- The unsharp mask is a **pixel-wise difference** between the original image and its smoothed (averaged) version
- Depending on the method of averaging this filter can be linear or nonlinear

Unsharp Masking

- Mask $g_{mask}(x,y) = f(x,y) - MEAN(S_{xy})$

  where $MEAN(S_{xy})$ is a mean over an n x m (typically 3x3 or 5x5 local window S_{xy} around pixel (x, y))
- Finally, filter is as follows

$$g(x,y) = f(x,y) + k \cdot g_{mask}(x,y)$$

- where k is a weight (parameter)

Unsharp Masking

- Unsharp masking leads to the enhancement of high frequencies
- It is the most efficient for 3x3 and 5x5 windows
- Averaging can be linear (arithmetic mean over a filtering window) or nonlinear (median over a filtering window)
- Unsharp masking enhances image details whose area is about a half by a half of the filtering window size

Unsharp Masking: Practical Implementation

- Unsharp masking linear filter

$$g(x,y) = f(x,y) + k\left(f(x,y) - MEAN\left(S_{xy}\right)\right)$$

- Filter kernel (mask) for a 3 x 3 window

$$\begin{pmatrix} -\frac{k}{9} & -\frac{k}{9} & -\frac{k}{9} \\ -\frac{k}{9} & k+1-\frac{k}{9} & -\frac{k}{9} \\ -\frac{k}{9} & -\frac{k}{9} & -\frac{k}{9} \end{pmatrix}$$

Unsharp Masking: Practical Implementation

$$g(x,y)=f(x,y)+k\Big(f(x,y)-MEAN\big(S_{xy}\big)\Big)$$

- The larger is *k*, the higher is a level of sharpening
- $k=1$ → regular unsharp masking
- $k>1$ → highboost filtering
- $k<1$ → slight enhancement of edges

Unsharp Masking: Practical Implementation

- Unsharp masking nonlinear filter

$$g(x,y) = f(x,y) + k\Big(f(x,y) - MED\big(S_{xy}\big)\Big)$$

Unsharp Masking: Global Frequency Correction (Frequency Emphasis)

- Unsharp masking can also be used to enhance simultaneously high and medium frequencies.
- This global frequency correction not only leads to image sharpening, but also can enhance details whose area is a half by a half of the filtering window size

$$g(x,y)=k_1 f(x,y)+k_2\left(f(x,y)-MEAN\left(S_{xy}\right)\right)+k_3 MEAN\left(S_{xy}\right)$$

- Again, depending on the method of averaging this filter can be linear or nonlinear

Unsharp Masking: Global Frequency Correction

- Global frequency correction linear

$$g(x,y) = k_1 f(x,y) + k_2\left(f(x,y) - MEAN\left(S_{xy}\right)\right) + k_3 MEAN\left(S_{xy}\right)$$

- Filter kernel (mask) for an *m* x *n* window

$$\begin{pmatrix} \frac{k_3 - k_2}{mn} & \cdots & \frac{k_3 - k_2}{mn} & \cdots & \frac{k_3 - k_2}{mn} \\ \cdots & & \cdots & & \cdots \\ \frac{k_3 - k_2}{mn} & \cdots & k_1 + k_2 + \frac{k_3 - k_2}{mn} & \cdots & \frac{k_3 - k_2}{mn} \\ \cdots & & \cdots & & \cdots \\ \frac{k_3 - k_2}{mn} & \cdots & \frac{k_3 - k_2}{mn} & \cdots & \frac{k_3 - k_2}{mn} \end{pmatrix}$$

Unsharp Masking: Global Frequency Correction

- Global frequency correction - nonlinear

$$g(x,y) = k_1 f(x,y) + k_2\left(f(x,y) - MED\left(S_{xy}\right)\right) + k_3 MED\left(S_{xy}\right)$$

Unsharp Masking: Global Frequency Correction

$$g(x,y) = k_1 f(x,y) + k_2 \left(f(x,y) - \bar{f}(x,y) \right) + k_3 \bar{f}(x,y)$$

- Bar over f stands for mean or median depending of which one of them us used
- The larger is k_2, the stronger is high frequencies enhancement (the best choice is $1 \le k_2 \le 6$)
- k_1, k_3 are responsible for a level of medium frequencies enhancement, they should be taken such that $k_1 + k_3 = 1$